Seismic sleuthing in southern California

October 11, 2019

Because large earthquakes are so infrequent, scientists don't have a good understanding of what triggers them. But now, thanks to a team that includes Laboratory postdoctoral fellow Daniel Trugman, scientists may be able to better understand how stress evolves in Earth's crust—and therefore how large earthquakes are triggered.

Trugman and colleagues from the California Institute of Technology and Scripps Institution of Oceanography analyzed nearly two decades of data collected from the 550 seismic monitoring stations in the Southern California Seismic Network (SCSN) that continually monitor movement in Earth's crust.

The SCSN catalog of recorded earthquakes has traditionally been based on visual analysis of seismic signals—an approach that Trugman says misses many weak seismic signals that are indicators of small earthquakes. These weak signals can sometimes get drowned out by background noise—things like traffic or mining, which also create signals.

So, to improve on the catalog, the team started data mining. Trugman likens the data mining process to a giant game of word search. Powerful computers are given a library of waveforms from previously recorded earthquakes. Each of these waveforms is broken down into scalable segments called templates. The computers then scan through continuous seismic network data for small signals that match the basic shape of the templates. "In the word search analogy, the templates are the words you are supposed to find," Trugman explains. "The network data is the letter grid, which is mostly a bunch of junk letters but has real words hidden inside."

After hundreds of thousands of hours, the computers were able to distinguish tiny quakes (less than zero magnitude) from background noise, and the team was able to detect, understand, and locate 1.81 million quakes—10 times more quakes than were previously identified using traditional seismology methods. This translates to an earthquake occurring in southern California every three minutes or so.

The team developed a comprehensive, detailed earthquake library for the entire southern California region, called the Quake Template Matching catalog. The catalog provides a more complete map of California earthquake faults and behavior.

Recently, Trugman and Los Alamos National Laboratory colleagues applied machine learning to study earthquakes created in laboratory quake machines. That work has uncovered important details about earthquake behavior that may ultimately be used to forecast future earthquakes.

“In the laboratory, we see small events as precursors to big slip events, but we don’t see this consistently in the real world. This big data template-matching analysis helps bridge the gap,” he says. “While the small earthquakes we detected aren’t dangerous, they are really important for understanding the physical processes that cause large, damaging earthquakes.”